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The effects of attentional focus and posture on suprapostural task performance: A developmental perspective.

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The Effects of Attentional Focus and Posture on Suprapostural Task Performance: A Developmental Perspective.

by

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ABSTRACT

Previous research has shown that healthy adults can improve task performance and postural control by the use of external attentional focus. The current study attempted to determine the effects of attentional focus on Pursuit Rotor tracking performance and postural sway in both children (age 9-11 yrs) and adults (age 18-25 years). Each participant completed 9 trials, 3 baseline measures, 3 seated posture measures and 3 standing posture measures. For the seated and standing trials, each participant was instructed to focus either internally, or externally, while tracking. An ATMI force plate was used to measure centre of pressure (COP). Overall, children had higher COP displacement and variability, and higher sway velocity than the adults. Adults exhibited better tracking performance than children, but children were able to achieve coupling between their sway frequency and tracking frequency, which indicates an interaction between the automatic processing of posture, and controlled processing of the task.

DEDICATION

In memory of my grandfathers, two men who exemplified personal integrity, leaving an everlasting impression that I will continue to embrace throughout my life.

ACKNOWLEDGEMENTS

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CHAPTER I

Introduction

The ability to enhance task performance by manipulating attentional focus strategies has been extensively examined by Wulf and colleagues (1998, 2000, 2001, 2002, 2003), who suggest that that there is an advantage to focusing attention on the effects of movement (external focus), rather than the movement itself (internal focus), to allow unconscious or automated processes to control performance. It has been suggested that the performance benefits of adopting an external attentional focus are effective with suprapostural activities and also in maintaining postural control (Wulf, Weigelt, Poulter, & McNevin, 2003). This can be explained by the notion of reduced attentional demands under the external focus condition. A greater degree of automatic processing in movement control (by external focus) is generally associated with reduced attention demands, so there are fewer interference issues occurring while performing the suprapostural task, leaving automatic processing available for postural control (Wulf et al., 2003). In both adults and children the ability to maintain balance is critical for the execution of motor tasks and interaction with the surrounding environment. Balance is maintained by keeping the individual's centre of mass (COM) within the base of support. When the stability of the individual is compromised the appropriate postural control strategy must be implemented or a fall will occur (Streepey & Angulo-Kinzler, 2002). During childhood, which is defined as the first 18 years of life, the body size increases by five times and the development of the nervous system occurs at the same rate (Lebiedowska & Syczewska, 2000). This rapid rate of development causes disproportion of the body and may result in weaker postural control strategies, thus resulting in an increased incidence of falls.

Previous research has indicated that maintaining upright posture is heavily dependent on sensory information available in the environment. Postural control can be altered by using sensory information with reference to other behaviours that might be engaged in during stance, such as visual tracking, walking, reading and manual manipulation (Stoffregen, Smart, Bardy & Pagulayan, 1999). Constraints imposed by these "suprapostural activities" influence postural adjustments. While studies from Stoffregen et al. (1999), Jeka Jeka, Oie, Schoner, Dijkstra and Henson (1998), and Smart, Mobley, Otten, Smith and Amin (2004) suggest that the postural control system responds to suprapostural tasks, it is unclear if maintaining postural control in an upright position has an effect on the suprapostural task performance. Optimal performance would be achieved if an individual could maintain postural control as well as sustaining an advantageous suprapostural task performance.

The studies previously mentioned were conducted on adult participants; this means that the results cannot be generalized across the life span, specifically with the child population. It is unclear whether or not children can use sensory information in the environment to experience the full benefits of adopting an external attentional focus while performing a suprapostural task. The current study will attempt to address this issue.

1.1 Statement of Purpose

The purpose of this study is threefold:

To quantify the effects of the attentional focus conditions (internal, external) on supra-postural task performance and postural sway.

To quantify the effects of age (9-11 and 18-25 years old) on performance of the supra-postural task and postural sway.

To quantify the effects of posture conditions (seated, standing) on performance of the supra-postural task.

Hypotheses

It was hypothesized that:

During the tracking conditions, participants using external attentional focus would have better tracking performance than participants using internal attentional focus.

During tracking conditions, children would exhibit larger centre of pressure displacement, larger centre of pressure variability, and higher velocity of centre of pressure, than adults.

During tracking conditions, adults would exhibit better tracking performance than children.

Adults and children would be able to couple the frequency of their sway with the frequency of the tracking task.

CHAPTER II

Review of literature

2.1 Information Processing

Early research on human performance would define attention as a link to the notion of conscious focalization on one out of many objects or trains of thought (James, 1890). In more recent research, this notion of consciously focusing on a thought or object would be defined as "controlled processing" (Schneider & Shiffrin, 1977). An example of controlled processing is learning a new skill; we must pay conscious attention to the skill to ensure that we are performing the skill correctly, and learning another new skill simultaneously, will disrupt learning the previous skill.

However, another type of attention required to control human movement, one that we perform on an unconscious level. Schneider and Shiffrin (1977) define this unconscious attention as "automatic processing". An example of automatic processing is limb and joint coordination during walking or a well practiced task that becomes a semi-automatic mechanism.

Controlled and automatic processing differ on many levels. Controlled processing is i) slow, ii) attention demanding, in that similar tasks may interfere with it, iii) serial in nature, iv) strongly volitional, in that it can be easily stopped or avoided, v) has a limited capacity, and vi) is flexible. In contrast, automatic processing is i) fast, ii) not attention demanding, other tasks do not interfere with it, iii) parallel in nature, iv) not volitional, in that they are unavoidable, v)has unlimited capacity, and vi) is inflexible (Schneider & Shiffrin, 1977).

The greatest advantage of a controlled process is the fact that it is very flexible, allowing for modifications in response to the environment. For example, when a novice is learning to perform a free-throw shot, they are using a controlled process and paying great attention to their form and proper technique. At this stage, he or she is quite malleable and would find ease in modifying his or her technique. If a professional basketball player were to attempt to modify his or her free-throw shot, they would have a difficult time doing so, as this skill has become more automated with practice and experience, and therefore less flexible to change. For example, we can walk and clap at the same time without one automatic process conflicting with another. However, recent thinking has suggested that controlled/ automatic processing element may be better though of as a continuum; where skills require varying degrees of conscious and unconscious attention (See Fig. 2.1).

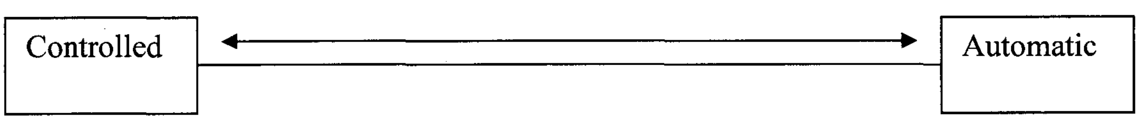

Figure 2.1- The controlled/automatic processing continuum.

Schneider and Shiffrin (1977) suggest that experience plays a role in the development of automatic processing. The more practiced a skill becomes, the less attention it requires thereby shifting to a more automatic mode of control. The most plausible explanation for this common pattern is that with increasing age, the physical system changes in some fundamental way that allows greater speed of both response and mental processing (Bee, 2000). For example, a child demonstrates controlled processing when he or she first learns how to ice skate, when limb movement and postural control will require constant monitoring. However, with experience and practice those movements become automated. Shallice and Burgess (1996) refer to this phenomenon as the 'construction of new schemas'. When one is learning a task, controlled processing allows the formation of a schema, which is defined as a 'known combination or expectancy' for the situation. With practice learners are able to refer back to this pre-existing schema, and implement new appropriate information into it for later reference with eventual automatic processing.

The idea of schemas also relates to Piaget's Stages of Cognitive Development (Bee, 2000), where not only experience, but cognitive development causes the generation of new schemas and the ability to increase the mental complexity of the schema by later childhood. Greater efficiency in processing is also gained because the child requires new strategies for problem solving. (Bee, 2000). The flexibility in controlled processing also may allow for the utilization of different performance enhancing strategies, specifically regarding attention, since the conscious attention thought process has already been activated.

One of the major distinctions between controlled and automatic processing is the use of attention. The current project will seek to examine the flexibility of the attentional mechanism. This will be done by manipulating the attentional focus demands.

2.2 Attentional Focus

Where we choose to focus our attention is an imperative part of our everyday lives whether we are at work, in school, or while performing a physical task. We may not always be conscious of the direction of our focus, as previously discussed, but it may still have an affect on our daily activities.

Recently, a number of studies have shown that a participant's focus of attention can have an important influence on motor performance and learning (Wulf & Prinz, 2001). Attentional focus refers to the conscious attendance to the internal (within the body) or external (outside of the body) components during the performance of an activity. Where we choose to focus our attention may actually hinder or enhance our performance and affect our outcome. Previous studies indicate that motor learning can be enhanced by directing the participant's attention to the effects of his/her movements ('external focus') rather than to the body movements producing the effect ('internal focus') (Wulf, Höß & Prinz, 1998). Throughout our childhood, we have consciously used both internal and external focus to learn skills. We have been instructed to focus externally ("keep your eye on the ball") to enhance our performance in tasks such as tracking a ball. However, we also explore the use of internal focus in tasks that increase our body awareness, such as gymnastics. So which focus of attention is most beneficial and why?

McNevin, Shea and Wulf (2003) hypothesized the notion of 'constrained action' to explain these attentional focus effects. According to the 'constrained action hypothesis', participants consciously attempt to control their movements and posture when asked to focus internally (or perhaps no instruction at all). As a consequence of internal focus, participants tend to experience information processing interference by consciously attending to too many kinesthetic cues. Unfortunately, this occurs because of the limited capacity or structural interference of controlled processing. By choosing to focus on numerous kinesthetic components, learners may not have the capacity to attend to the demands of the task, or they may not be able to process in parallel multiple kinesthetic cues, resulting in a poor performance. The hypothesis of constrained action states that once this overload of information occurs, the learner tends to constrain their motor system by freezing their degrees of freedom which may disrupt control processes that may otherwise be automatic.

In contrast, external attentional focus allows the learner to focus on the effects of the movements, which requires less information overload and reduces structural interference. Rather than focusing on the control of a variety of intricate limb movements, the learner can allow those movements to resume their automaticity by consciously attending only on the attention demanding task. This may result in a more effective performance and learning process by allowing the appropriate automatic processes to occur without interruption caused by overloading of the controlled processing system.

2.3 Attentional Focus and Task Performance

When one uses controlled processing to focus on the environment outside of the body while performing a task and devotes attention to that task, a more liberal operation of automatic processes may emerge by avoiding attention disruptions. Support for the notion that the adoption of an external focus promotes the exploitation of more automatic control processes comes from a study done by Wulf, McNevin and Shea (2003). Participants were given the task of balancing on a stabilometer and instructed to adopt either an internal (focus on feet) or external focus (focus in front of feet). Faster probe reaction time was found for the external focus group compared to the internal focus group, suggesting less disruption to the stabilometer task when focusing outside the body. Furthermore, the frequency characteristics of the platform movements demonstrated higher frequency adjustments for external focus conditions representing the incorporation and coordination of additional degrees of freedom. Therefore, by adopting an external attentional focus for completing the task, less interference was experienced thereby allowing the automatic processing of postural balance on the stabilometer to take place.

2.4 Novice Learners and Attentional Focus

Due to the fact that novice learners use controlled processing to learn new tasks, they are also most susceptible to processing interference by attending to too many components of the movement. As a result of the enhanced flexibility within controlled processing, it is likely that novice learners would accept and even benefit from the introduction of external attentional focus instructions.

Wulf, Shea and Park (2001), conducted a study that examined the preferences for and the advantages of an external focus for novices during skill acquisition and retention. The task required participants to balance on a stabilometer and to remain in balance (keep platform in horizontal position) for as long as possible during each 90-s trial. Prior to the acquisition trial period, participants were given the option of adopting either an external focus, which was focusing on the markers in front of their feet or an internal focus, which was focusing on their feet. During the acquisition trials, 10 out of the 17 participants self-reported that they chose to focus on their feet (internal focus); however, participants who chose to focus internally experienced a decreased performance in the retention trials, which were conducted one day after the acquisition trials. During the retention test those who chose to focus externally during acquisition trials had better performance than those that chose to focus internally during acquisition. These results suggest that perhaps the individuals who chose to focus externally during the acquisition trials formed more constructive schemas that they were able to refer to later during the retention trials. This suggests that the benefits of external focus are not acute, but perhaps generate a more vivid mental representation or schema for the learner to use in future performances.

2.5 Children and Attentional Focus

It has been shown that a novice learner benefits from adopting an external focus during task performance, but given the differences in cognitive processes, and schema development in children and adults, a primary interest of the current study was to determine if children have the capacity to adopt a similar attentional focus strategy. In the current study, the age range of the child participants was 9 to 11 years old, which reflected the Concrete Operational Stage of Piaget's Stages of Cognitive Development. It is during this stage that children learn to apply logical schemes to a wider range of tasks.

Development of concrete operational thinking can best be understood in terms of gradual gains in information processing capacity rather than a sudden shift to a new stage. With experience, schemas demand less attention and become more automatic, thus resulting in faster processing and improving the ability to combine old schemas and generating new ones (Bee, 2000).

Bryanton, Bossé, Brien, McLean, McCormick and Sveistrup (2006) examined the use of Virtual Reality (VR) to enhance motor function in children with and without cerebral palsy (CP). The VR represented an external focus condition, in that the participant was focusing on the effect of the movement rather than the movement itself. There were 10 children with CP and 6 typically developed children, all between the ages 7-17 years old, recruited for the study. The task required each participant be in a seated position and to dorsiflex his or her ankle to the end of his or her available range of motion, and hold the maximal position for 3 seconds and relax. The participants were divided into a control group, and a VR group. The control group did not receive VR, and were given conventional instructions for motor rehabilitation, which included stretching and instructing the child to consciously attend to the improvement range of motion in the ankle. The VR group was seated in front of a screen that displayed a program that combined the child's image with an exercise scenario, a game in which they could keep score. The VR group was able to interact with the virtual objects in the environment; for example, when the child would dorsiflex his or her ankle to a certain range, a VR ninja would do a flip off of his or her toe. Range of motion and holding time was measured, as well as a perceived enjoyment questionnaire following the rehabilitation. All children responded to the questionnaire with higher enjoyment and interest scores for VR than conventional exercise. Also, participants with and without CP were able to achieve longer flexion hold times with the use of VR. By using the VR, the amount of information that the child needed to attend to was reduced, and the child was able to free his or her degrees of freedom to complete the task. This suggests that when a child is provided with external attentional focus strategies, such as VR, he or she can demonstrate better automatic control of ankle dorsiflexion movement and report greater interest completing the task.

Previous literature has suggested that children are able to use attentional focus to overcome situational restrictions, but it is still unclear if children can use attentional focus as a controlled process to facilitate the automatic control of posture during task performance, a mechanism that is crucial to motor development.

2.6 Postural Stability and Attentional Focus

Wulf et al. (2001) have shown that external focus is beneficial in the motor task of shifting one's weight in a skillful pattern when using a stabilometer, but can these results be applied to the skills required to maintain one's balance? In a related study, Wulf et al. (1998) required novice participants to learn to balance on a stabilometer. One group was instructed to focus on keeping their feet horizontal (internal focus), whereas another group was instructed to focus on keeping two markers, attached to the stabilometer platform (external focus) directly in front of their feet, horizontal. The results of the study indicated that participants who were instructed to focus externally, demonstrated lower error and reported focusing externally more favourable than participants who were instructed to focus internally (Wulf et al., 1998). Similar to previous findings, adopting an external attentional focus, allowed the automatic processing of balance to occur without conflict. Focusing externally was found to be beneficial in performances that required gross motor skills or balancing abilities with inexperienced participants who were provided with attentional focus instructions.

2.7 Postural Control as an Automatic Process

Posture can be defined as the orientation of any body segment relative to the centre of gravity (Winter, 1995). When an individual is maintaining a quiet upright stance, there are numerous automatic processes in the body that are integrated to control posture. The central nervous system (CNS) is continuously controlling the multi-segment system for successful inter-limb coupling that can facilitate balance control. This occurs through automatic detection and correction mechanisms that occur with respect to an individual's centre of pressure (COP) and centre of gravity (COG). COP is defined as the point location of the vertical ground reaction force vector; represents a weighted average of all pressures over the surface area in contact with the ground, whereas COG is vertical projection of the total body mass in the global 3-D reference space (Winter, 1995). When the CNS senses a shift in one's COG, the COP must be continuously moving anteriorly and posteriorly to maintain balance (Winter, 1995) (see Fig. 2.2). Therefore, when one is standing still, the COP is always swaying around the centre of gravity.

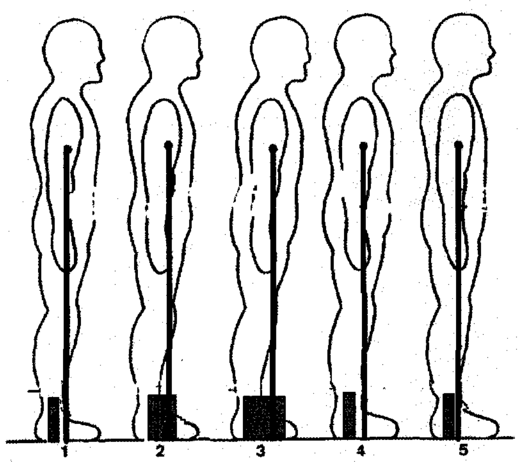

Figure 2.2- Diagram of COP and COG relationship. The COG is represented by the thick black line, and the COP is represented by the shaded box. As the body moves forward, the COP adjusts to regain balance. (Modified from Winter, 1995, p.195)

Maintaining postural control is an automatic process due to the amount of experience with standing and walking, which means that these adjustments of the COP occur rapidly and without attention (Schneider & Shiffrin, 1977). Adults have more experience with walking and standing postural control, thus having better detection and correction automatic processes without overcompensating for COG displacement. Due to the high degree of automaticity in developed postural control, there is less flexibility for change. It is likely that a large perturbation would be required to disrupt the system (Schneider & Shiffrin, 1977).

Previous research has shown that a typical postural characteristic of healthy adults is that they exhibit greater sagittal sway than lateral sway during a two legged stance

(Suomi & Koceja, 1994). This means that the automatic detection and correction mechanisms are primarily active in the sagittal plane to maintain balance. Children would have less experience with developing these detection and correction mechanisms, which causes them to control their posture differently than adults, and perhaps even use controlled processing at times.

2.8 Postural Control in Children

In contrast to adults, children exhibit a larger magnitude and velocity of COP displacement. Young children may employ a primarily high velocity, ballistic strategy, making large and fast corrections of centre of pressure to ensure stability (Riach & Starkes, 1994). Children lack the ability to minimize postural sway, when necessary, and overcompensate at a high velocity when the COP leaves the position oriented to the COG which is the most stable position.

A significant age dependence of the postural measures has been demonstrated from a longitudinal study by Kirschenbaum, Riach and Starkes (2001) who showed that the control strategy to maintain balance does not follow a simple linear relationship with age, but a step-like transition at the age of 6 to 8 years occurs. The results from this study indicate that there was a decrease in velocity after 7 years of age, which suggested improved sensory calibration (see Fig 2.3). That is, the children may have become better at estimating where they were relative to the COG and incorporating more automatic sensory processing to gain stability.

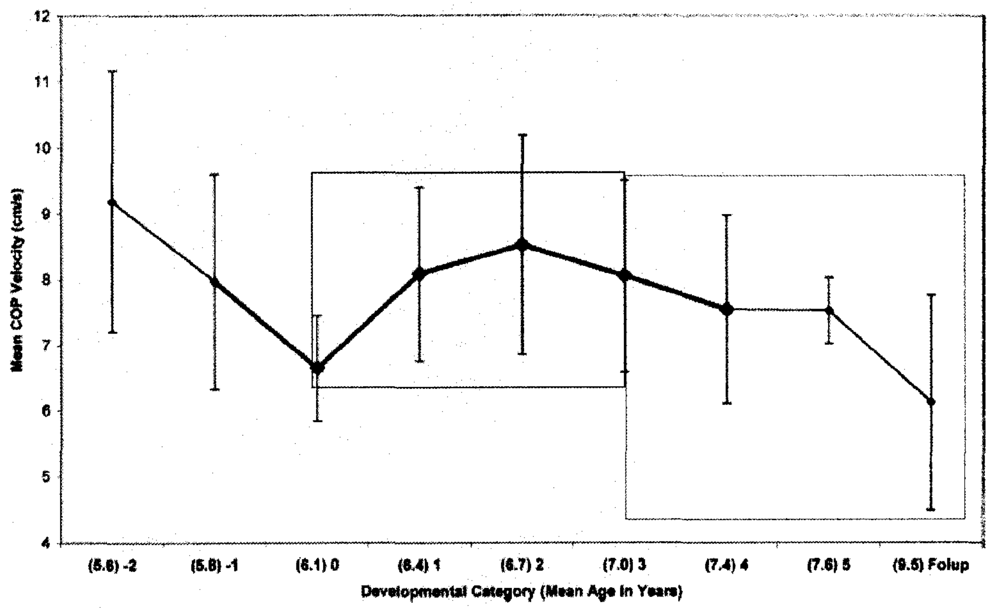

Figure 2.3 - Mean COP velocity as a function of age. The blue and red boxes represent a transition point whereby following an increase in velocity prior to age 7 years, there is a decrease up to 9.5 years. (Modified from Kirshenbaum et al., 2001, p.425)

The adoption of this automatic process also has a direct effect on the strategies used to control anterior-posterior (AP) COP displacement. Figure 2.4 depicts the linear decrease in mean AP COP displacement between ages 5.6 and 9.5 years of age. Results also indicated that there was a 'plateau' period between 6 and 7 year of age. This plateau period coincided with the increased velocity of COP displacement (see Fig 2.3-red), which may indicate the adoption of new postural strategies after 7 years of age.

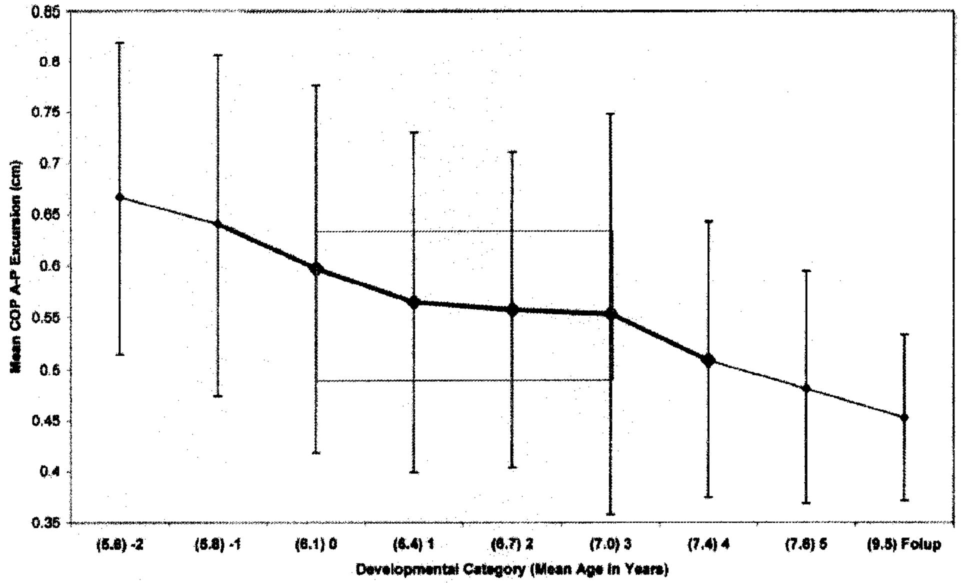

Figure 2.4- Mean COP excursion in the A/P direction as a function of age. This excursion was measured relative to an alignment of zero. The green box represents stabilization in excursion distance between the ages of 6.1 and 7.0 years of age. (Modified from Kirshenbaum et al., 2003, p.426)

Riach and Starkes (1994) examined the use of sensorimotor open loop and closed loop feedback systems in maintaining postural stability in children ages 4-13 years old by asking children to lean as far as they could in the four directions (forward, backward, left, and right) while standing. The results indicated that there was a main effect for age, with differences emerging between the age clusters of 4-7 year olds and 8-13 year olds. Velocity of the COP was highest for 4-7 year olds and lowest for 8-13 year olds. These results may suggest that the younger children (4-7 years old) who showed a higher velocity may have been using an open loop control system, since they had not yet learned to detect and use sensory information for a closed loop system. The older children (8-13 years old) had a lower velocity because they had the ability to use a closed loop system and make online error detection and corrections, which was more time consuming than an open loop system with no feedback. These results suggest that, with experience the child may have developed new schemas, which take into account both open loop and closed loop components of the automatic processing of balance control.

The findings from Riach and Starkes (1994) and Kirshenbaum et al. (2001) indicate that there was a transition period that occurred around the age of 7 years old. To ensure that this transition period did not affect the children between the ages of 9 to 11 years were studied.

In summary, previous literature suggests that children use different postural control mechanisms to maintain upright stance than adults; and adults are able to effectively use external focus strategies to allow the emergence of more fluid postural control for increased performance. It is critical to have more automatic processing in controlling posture while completing a task that requires attentional demands for optimal postural control and task performance.

2.9 Suprapostural Effect on Quiet Stance

Stoffregen, Smart, Bardy and Pagulayan (1999) conducted a study that examined the relations between postural sway, optical flow, and constraints on posture imposed by a suprapostural looking task. There were 8 undergraduate students, with ages ranging from 18 to 28 years that participated in the study. All participants had normal or corrected-to-normal vision and all reported no history of dizziness, instability or falls. The participants were also naïve to the purpose of the study. Each participant stood in a room where they were positioned 3m from all surrounding walls. There was both a near and far target set up in the room. The far target was a rectangle painted on the wall, measuring 107cm high by 6cm wide, at a visual angle of 18.2°(vertical) and 11.6°(horizontal). The near target was an object placed at eye height, 0.4m in front of the eyes, and adjusted for each subject to ensure the same visual angle for both near and far targets. From the visual perspective of the participant, the near target should appear directly below the far target. Spontaneous postural sway was measured using a magnetic tracking system, that consisted of emitters and receivers that were positioned on the participant's head. There were three conditions tested: no object-far, object-near, object-far. In the no object-far condition each participant was instructed to fixate on the far target while the near target was not present. In the object-near condition, the participants were asked to fixate on the near target object, and in the object-far condition, the participants were asked to fixate on the far target, but this time the near object was in place. There were four 70-s trials for each of the three conditions, with all conditions counterbalanced across participants.

The results indicated that there was a significant difference in anterior sway patterns between the no-object far and object near conditions as well as the object-near and object-far conditions. The no object-far condition showed the highest variability of both AP and mediolateral (ML) sway, 0.9cm and 0.37cm, respectfully. The object-near condition showed the least amount of AP and ML sway, 0.6cm and 0.28cm, respectfully; while the object-far condition fell in between. The results indicated that both AP and ML sway was minimized when one could visually fixate on an object that was closer to their body. Also, there was still a reduction in AP and ML sway when one visually fixates on an object far from the body but has visual reference with an object in the same visual field. These results showed that with the introduction of a static object on which one can visually fixate; there was a spontaneous decrease in postural sway. While these results are compelling, it was not clear if the impact on postural control would be present if the demand of the supra-postural task were beyond simple fixation.

2.10 Attentional Focus and Suprapostural Tasks

Current studies have shown that suprapostural tasks have been effective in minimizing excessive postural sway, and that by adopting an external attentional focus one can enhance his or her performance. An issue that deserved further consideration is whether there are benefits to the automatic processing of posture if the controlled processing is used to manipulate attentional focus during a suprapostural task? McNevin and Wulf (2002) examined this question by investigating the addition of a suprapostural task and attentional focus, induced by the suprapostural task instructions.

The task consisted of three 30-s trials. During each trial the participant was instructed to stand quietly on the force platform with feet shoulder-width apart. Prior to the attentional focus instructions a baseline measure of posture in both the AP and ML direction was recorded. For the attentional focus trials, the participant stood on the force platform with a coat rack directly in front of them with a white sheet draped over it. The participant was required to make light contact with the sheet using the tip of his or her index finger. The internal attentional focus condition required that the participants focus on minimizing the movement of his or her hand and index finger throughout the trial. The external attentional focus condition required that the participants focus on minimizing the movement of the sheet throughout the trial. Results indicated that the external attentional focus condition produced a higher frequency of postural responses than both the internal and baseline conditions. Similar to previous research, the reduced attentional demand of external focus allowed the automaticity of the postural system to emerge and result is faster operation (Schneider & Shiffrin, 1977). These results suggest that not only does the addition of a suprapostural task affect one's postural sway but also that the type of attentional focus one adopts during the duration of the task can affect postural sway.

Wulf et al. (2001) have shown that adopting an external attentional focus facilitates balance learning and task performance, and Stoffregen et al. (1999) have shown that postural stability can be enhanced by the addition of a suprapostural task. However, when we are required to both maintain balance and adopt an external focus while performing a suprapostural task, does the presence of both automatic and controlled processing cause one to take precedence over the other, or can both balance and suprapostural task performance be enhanced? Wulf, Weigelt, Poulter and McNevin (2003) examined whether the focus of attention adopted for a suprapostural task can affect the suprapostural task performance and also enhance the performance of dynamic balance learning. The study consisted of practice trials that took place over two days, each with seven trials, and seven retention trials on the third day. The postural element of the task was to balance on a stabilometer platform and try to maintain a horizontal position over a 90-s trial. The stabilometer platform had two markers on the surface and participants were instructed to place their feet behind the markers. The horizontal displacement of the stabilometer was measured by a potentiometer linked to the platform. The suprapostural task required the participants to use both hands to hold a wooden tube in a horizontal position, at a height where they could visually monitor it. At the beginning of each 90-s trial a ball was placed in the centre of the tube and if the tube was displaced from the horizontal position, the ball rolled to the right or left side of the tube and an auditory signal was emitted. The participants were instructed to try to keep the ball in the centre of the tube. Attentional focus instructions were varied across participants. The internal focus participants were instructed to focus on keeping their hands in a horizontal position and the external focus participants were instructed to keep their focus on the position of the tube. The participants' performance on the postural task was measured by root mean square error with the 0° position being the criterion. The performance on the suprapostural task was measured by the number of times the ball in the tube hit either end of the tube, producing the auditory signal, which indicated deviation from the horizontal position. Wulf et al. (2003) reported that the participants who were instructed to adopt an external focus had 150% fewer errors during practice and 400% fewer errors during retention on the suprapostural task. For the balance task, again an external focus led to a superior performance during both the practice and retention trials. The fact that external focus allows more automatic processing to control balance means that the participant can also devote more attention to the controlled processing of the task performance, resulting in better postural control and better task performance. While this is true for simple motor tasks, does this phenomenon occur when a more demanding suprapostural task is performed?

2.11 Suprapostural Task Demands

Smart, Mobley, Otten, Smith and Amin (2004) investigated how postural coordination was modified as a function of changes in suprapostural task constraints by having participants standing while performing a letter-counting task. Participants were aware of the fact that their posture was being analyzed, but not the actual goals of the study. Postural sway was measured by a magnetic tracking system. The suprapostural task was to read a short passage and count the number of "e's" and "o's" in the passage. The letters were similarly shaped and had similar frequency in the passage, causing the task demands to be high and requiring a great deal of attention. Similar to the study by Stoffregen et al. (1999), three conditions were used with the far target present in all conditions, but instructions for focus varied. In the object-near condition, the participant was instructed to read a passage that was 0.4m in front of the participant, in the object-far condition the participant was to read a passage that was placed on the wall 3m from him or her, and in the no object condition the participants focused on the far target without the near target (passage) present. The size of the letters was scaled so that they appeared the same size and visual angle for each distance. In the object-near condition, letter-counting accuracy was slightly better than other conditions, and the no object condition showed the lowest score in accuracy. Thus, suprapostural task proximity was most beneficial for task performance. The results regarding postural sway parallel those reported by Stoffregen et al. (1999) in that the object-near condition showed the lowest AP and M/L sway, 0.47cm and 0.41cm, respectfully, compared to both the no object and object-far conditions. Also, the no object condition showed the most AP and ML sway, 0.79cm and 0.72cm, respectfully. From these results we can say that when the demands of the suprapostural task require more attention, there was still a decrease in postural sway, so as long as the task was within a close visual range or that there was a proximal visual reference point.

This indicates that when a suprapostural task requires more controlled processing, it is actually beneficial to the postural system, allowing automatic processing to operate at an optimal level. As such, Stoffregen et al. (1999) and Smart et al. (1999) demonstrated that postural sway was affected by a visual suprapostural task, but what postural characteristics are present if the supra-postural task requires manual tracking?

Jeka, Oie, Schoner, Dijkstra and Henson (1998) examined the postural reactions to a dynamic manual supra-postural task. Undergraduate participants were instructed to stand on a force plate in a heel-to-toe stance with the tip of the right index finger in contact with a flat touch plate (See Fig.2.5). The touch plate was driven rhythmically by a torque servo drive with the tip of the right index finger in contact at frequencies of 0.1, 0.2, 0.4, 0.6, and 0.8 Hertz (Hz). A self-sticking dot was located in the middle of the touch plate to reduce fingertip sliding and ensure contact with the touch plate throughout the trial. The goal of the task was to maintain balance while keeping contact with the dot. The ML position of center of pressure was calculated from ground reaction forces measured by the force plate.

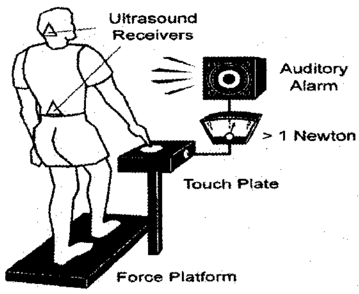

Figure 2.5 - Testing apparatus. (Modified from Jeka et al., 1998, p. 1662)

Results showed that the participants exhibited strong coupling between body sway and touch plate movement, indicating that the postural control system was responding to the frequency of the touch plate. Therefore, the controlled processing of maintaining contact with the touch plate actually entrained the automatic postural system. It was also shown that the strength of coupling was frequency dependent. "Mean frequency of the COM matched the touch plate frequency when it was ≤ 0.4Hz (see Fig.2.5-red) and decreased for frequencies exceeding 0.4Hz perhaps due to phase lags in velocity and reduced damping at higher frequencies" (Jeka et al., 1998, page #) (see Fig.2.6).

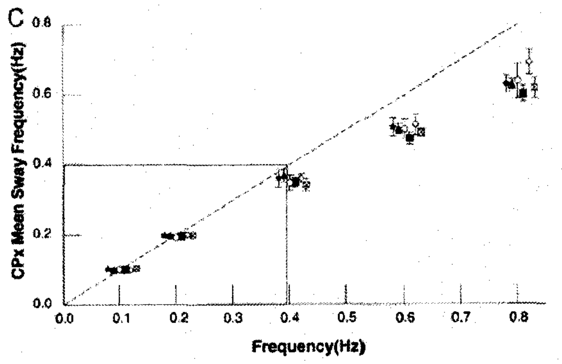

Figure 2.6 - Mean COP displacements for all subjects as a function of touch plate frequency. The red box highlights the linear relationship between sway frequency and touch plate frequency up to 0.4 Hz. (Modified from Jeka et al, 1998, p1665).

The results of Jeka et al. (1998) suggest that the postural system was capable of adapting to a dynamic haptic world, which is a crucial component in maintaining one's balance, thus preventing falls, and suggests that the introduction of a manual supra-postural task allows coupling of the adult postural system at lower frequencies. While this coupling effect was the result of the introduction of a suprapostural task, would the use of attentional focus during the suprapostural task be even more beneficial?

McNevin, Weir, Wulf and Quinn (2005) examined postural sway and tracking performance within an attentional focus framework for both young and older adults. The dynamic supra-postural task required participants to manually track a target at frequencies of 0.5Hz and 1.0 Hz on a Pursuit Rotor apparatus. Total sway of the COP in both AP and ML directions were quantified over three 20-s trials using a force plate. All participants were required to maintain an upright stance while measures of tracking performance were calculated as time on target (TOT). This was a within subject design as each participant performed a quiet baseline measure, trials using internal attentional focus and trials using external attentional focus. Under the 0.5Hz tracking frequency, older adults exhibited higher postural sway measures under internal focus than the younger counterparts in the ML direction. In the AP direction, older adults generated higher postural sway regardless of tracking frequency or focus condition. The older adults may use more controlled processing to maintain balance, which would cause them to respond at a slower rate, thus resulting in more unnecessary displacement (Schneider & Shiffrin, 1977). These results suggested that with older participants, postural sway can be influenced by suprapostural task difficulty, but seems amenable to external focus to allow more automatic processes to surface. Considering the results of this study, the current study examined the effects of attentional focus and posture on an upper-limb tracking task in both young adults and children.

Based on previous literature, we understand that there are different biomechanical and information processing mechanisms of maintaining posture that exist between children and adults. However, it has been demonstrated that adult posture can be influenced by the presence of attentional focus strategies during the performance of a suprapostural task. The current study examined these findings from a developmental perspective.

CHAPTER III

Design and Methodology

3.1 Participants

A total of 40 participants, (20 children, 20 adult) divided into age groups of 9-11 years and 18-25 years, were studied in this experiment. All participants were female and right-hand dominant which was assessed by asking the participant which hand they would write with. The child participants were recruited from recreational summer camps held at the St. Denis Centre at the University of Windsor, the adult participants were recruited from summer undergraduate and graduate courses.

The participant's age was recorded and their height and mass were measured prior to testing. A general health questionnaire (Appendix A) was administered to ensure that the participant did not have a history of balance, neurological or shoulder rotation problems, which would prevent them from completing the protocol. The parent/guardian of each child participant was asked to fill out the general health questionnaire on his/her child's behalf. Prior to initiation of the study, each participant was provided with a consent form (Appendix B) approved by the Research Ethics Board at the University of Windsor. For the child participants, the consent form was given to his/ her parent/guardian upon recruitment, to be signed and returned before the study.

A between-subject design was used to eliminate any confusion that may exist by presenting each participant with both focus conditions. Each participant was assigned to either an internal focus group or an external focus group. There were a total of 4 groups: i) Child Internal Focus, ii) Child External Focus, iii) Adult Internal Focus and iv) Adult External Focus. Due to the high variability present in children, each participant acted as their own control measure (baseline).

3.2 Experimental Equipment

3.2.1 Force Platform

The postural sway data (centre of pressure – COP) was collected using an Advanced Mechanical Technology Inv. (AMTI) force plate. The AMTI platform is a static-force measurement system comprised of an array of force transducers and amplifiers that converts the physical force to voltage that represents instantaneous values of applied force. The direction of force application was measured in both the anterior-posterior (AP) and medial-lateral (ML) dimensions. Voltage was recorded using an analog-to-digital converter interfaced with an IBM compatible computer, and configured to sample at a frequency of 1000Hz. All conversion, filtering, and processing of force data was performed using the LabVIEW software program. The raw data was low passed filtered at 5Hz using a Blackman Harris finite impulse response (FIR) with 25 data points in each window.

3.2.1.1 Dependent Variables

i) Mean Power Frequency (MnPf): the mean frequency of the power spectrum across all frequencies represented in the COP signal.

ii) Total Displacement and Standard Deviation (SD): Total Displacement represents the difference between the maximum and minimum COP displacement raw data over the 40-s baseline trial and 20-s tracking trial. SD represents the variation around the mean COP. The LabVIEW data plot is depicted in Fig. 3.2.

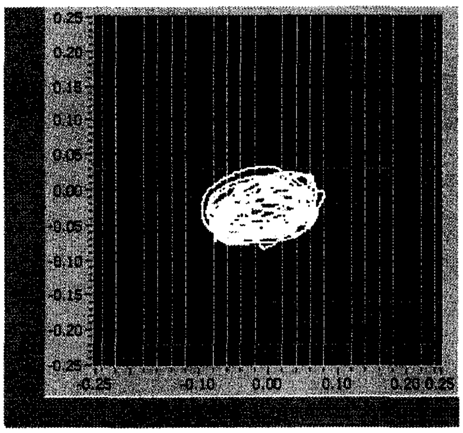

Figure 3.2- Sample LabVIEW aerial view of a participant's centre of pressure while tracking.

iii) Velocity of COP: the velocity of the COP represents the Total Sway length divided by the trial time (Baseline 40s, Tracking 20s).

iv) Coupling: the relative measure of MnPf of the COP compared to the tracking frequency of the pursuit rotor, which was calculated to determine the influence the tracking frequency on the postural control system. This was calculated by dividing the participant's MnPf during tracking by the tracking frequency of the Pursuit Rotor. A relative tracking value of 1.0 indicated that the participant's dominant sway frequency was equal to that of the tracking frequency, and a value greater than 1.0 indicated that the participant was swaying at a higher frequency than the tracking frequency, while a value less than 1 meant that the participant was swaying at a lower frequency than the tracking frequency.

3.2.2 Pursuit Rotor

A Photoelectric Pursuit Rotor (PR) apparatus, (Lafayette Instruments Co.) was used for the supra-postural task. The dimensions of the PR screen were 14"x 14" and the size of the illuminated target was 1" x 1" (see Figure 3.3).

The diameter of the tracking circle was determined by a pilot study where we measured the arm length of 6 adults and 6 child participants. The tracking template provided by Lafayette Instruments Co. had a tracking diameter that was 56% of the average adult arm length. To ensure that the tracking task was the same for both adults and children, a child size tracking template was created with a diameter that was 56% of the average child arm length. The participants were asked to perform the tracking task in both seated and standing positions. The seated position served as a baseline measure for suprapostural task performance where there was less demand of postural control. The PR was positioned so that the centre of the rotating disk was at eye level.

For the standing conditions, the PR was positioned vertically approximately 10" in front of each participant and aligned so that the centre of the rotating disk was at eye level. The participants were instructed to stand with feet shoulder width apart. The participant's task was to manipulate the hand-held stylus so as to ensure direct contact between the tip of the stylus and the illuminated target (See Figure 3.3). In the seated condition, the participant was seated comfortably on a straight back chair with their feet resting comfortably on the floor. The PR was placed on a secured adjustable shelf that could be adjusted to a maximum height of 168cm and a minimum height of 49cm, which allowed each participant to track, both seated and standing, at a height that was individualized to their eye level, to ensure consistency among participants (See Figure 3.4).

Figure 3.3- Pursuit Rotor on adjustable shelf, used for upper limb tracking task.

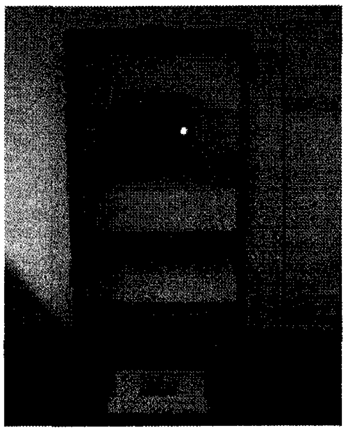

Figure 3.4- Adjustable shelf positioned anterior to the force plate.

3.2.2.1 Dependent Variable

The LabVIEW software was programmed to calculate the time that the stylus was in contact with the illuminated target (Time on Target- TOT). This value was represented by a percentage of the 20-s trial time.

3.3 Data Acquisition

3.3.1 LabVIEW Software

LabVIEW (National Instruments, Austin, TX) was used to develop both the data acquisition and processing software. The software received data from both the force platform and the pursuit rotor where the dependent measures were plotted and transferred into data files.

3.4 Testing Protocol

The collection of data took place over one session that lasted approximately 25min. Instructions outlining the demands of the study were described to the participant and any further questions were clarified. The complete testing session consisted of 9 trials, three baseline trials lasting 40-s each and the 6 tracking trials lasting 20-s each. The baseline condition was always performed first. Within each focus condition, the postural conditions (seated, standing) were counterbalanced to ensure that order or experience did not affect the results. The participants in the Internal Focus group were instructed to focus on keeping the tip of their finger in line with the rotating light while tracking with the stylus. The External Focus group participants were instructed to focus on keeping the tip of the stylus in line with the rotating light while tracking with the stylus.

3.4.1 Baseline Postural Sway

The participant was asked to stand on the force platform with their feet placed on the surface of the platform, reflecting a shoulder width, stable stance. The participant was asked to stand quietly and focus on the red sticker at eye level in the centre of the PR screen in front of them. At this time, the postural baseline measure was taken over three trials.

3.4.2 Tracking Frequency

The baseline postural sway measure was then used to determine the Tracking Frequency, which was the speed of the Pursuit Rotor. The average baseline MnPf frequency for each participant was calculated directly after the baseline trials and then the Tracking Frequency for the tracking trials was set to 120% [1]of the mean baseline MnPf.

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[1] The value of 120% was determined from pilot work involving the baseline MnPf measures of 8 participants and a previous study by McNevin et al. (2005) where participants were challenged at 140% of their MnPf, which resulted in very poor tracking performance.

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3.4.3 Standing Condition

The standing condition measured the effects of the suprapostural task and attentional focus conditions on postural sway. Each participant performed 3 trials of either the internal focus condition or the external focus condition. The standing posture was similar instructed to hold the stylus with his or her dominant hand with his or her thumb on the top of the stylus.

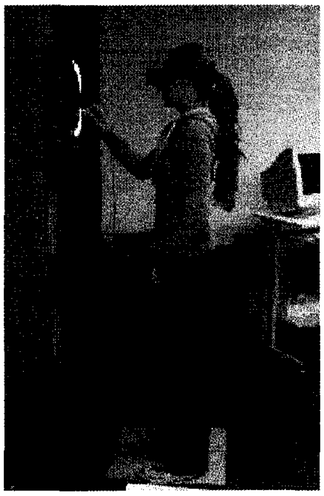


Figure 3.5- Participant tracking in the Standing condition.

3.4.4 Seated Condition

The seated posture measured the suprapostural task performance (PR tracking performance), without the demand of maintaining an upright posture. This was to examine if there was a causal relationship between suprapostural task performance and maintaining upright postural control. The participant was seated comfortably in an upright chair with his or her feet planted firmly on the ground to ensure stability. At this time the height of the PR was adjusted by changing the placement of the shelves to make certain that each participant was tracking at eye height. As with the standing posture condition, each participant was tested on either the internal or external attentional focus conditions. The only difference was that the participant no longer had to maintain upright posture (See Figure 3.6)

Figure 3.6- Participant tracking in the Seated condition.

3.4.5 Statistical Analysis

The dependent measures of the study were the MnPf in the AP and ML directions, Total sway path in both the AP and ML directions, SD of the COP, velocity of the COP in both AP and ML directions, coupling, and the % TOT for the supra-postural tracking performance. There were two between subject factors: Group, comprised of two levels (Child and Adult) and Attentional Focus, comprised of two levels (Internal and External). There were two within subject factors: Trial comprised of three levels (1, 2, 3) and Posture, comprised of three levels (baseline, standing, seated).

The measures for tracking trials and baseline trials were analyzed separately using a variety of analyses for each of the dependent variables: For all postural dependent variables (MnPf, SD, Total Sway Path, Velocity, Coupling) a 2 (Focus) x 2 (Group) x 3 (Trial) Mixed ANOVA was performed with repeated measures on the Trial variable. For the performance dependent variable (% TOT) a 2 (Focus) x 2 (Group) x 3 (Trial) x 2 (Posture) Mixed ANOVA was performed with repeated measures on both the Trial and Posture variables.

Alpha (α) was set to 0.05 for all analyses. All significant main effects and interactions were post-hoc tested using the Tukey HSD test.

CHAPTER IV

Analysis of Results

4.1 Participants

All participants were female and were right hand dominant in the task of handwriting. The anthropometrics for the participants are outlined in Table 1.

GROUP	FOCUS	# of Subjects	AGE (yrs)	HEIGHT(m)	WEIGHT(kg)
CHILD	Internal	10	9.71 (0.95)	1.43 (0.14)	36.0 (8.70)
CHILD	External	10	10.30 (0.67)	1.43 (0.15)	43.83 (5.74)
ADULT	Internal	10	21.90 (2.42)	1.67 (0.61)	58.85 (3.46)
ADULT	External	10	23.14 (2.54)	1.73 (0.66)	65.57 (9.53)

Table 1. Subject Anthropometrics (SD)

4.2 Postural Measures

All postural parameters were measures of centre of pressure. Figure 4.1 is a centre of pressure graph, which displays an aerial view of the centre of pressure which is measured by the force plate. Figure 4.1 (a) is a plot from a Baseline condition, where there was little movement of the centre of pressure as the participant was asked to stand still. Figure 4.1 (b) is a plot from a Tracking condition, where the body experienced greater displacement or sway, causing the centre of pressure to have greater postural measures, specifically in the mediolateral (ML) direction.

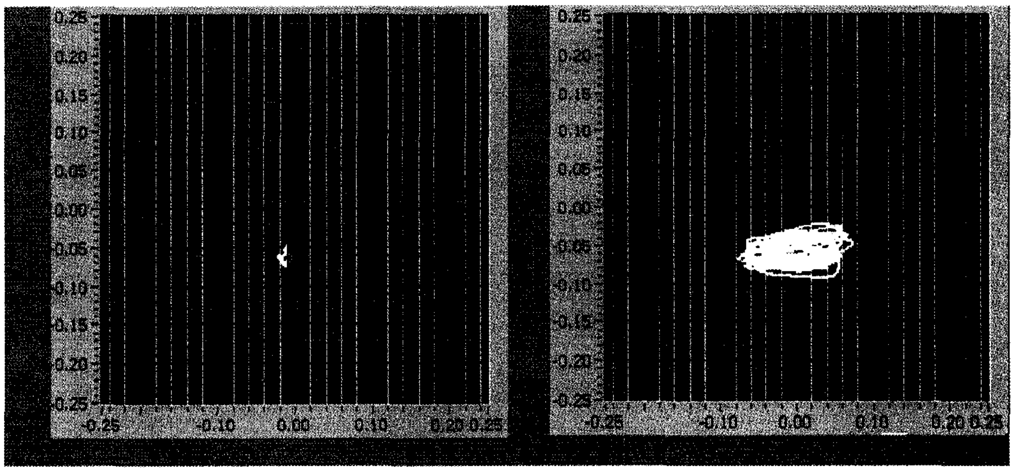


Figure 4.1a- Baseline adult COP Plot (m); 0.00 represents no displacement.

Figure 4.1b- Tracking adult COP Plot (m); 0.00 represents no displacement.

4.2.1 Total Displacement

The analysis performed for anteroposterior (AP) total displacement revealed significant main effects for Group in both Baseline [F (1, 38) = 9.26, p≤0.05] and Tracking [F (1, 36) = 23.41, p≤0.05] conditions. Child participants showed a significantly greater AP total displacement than the adult participants, in both conditions (See Figure 4.2).

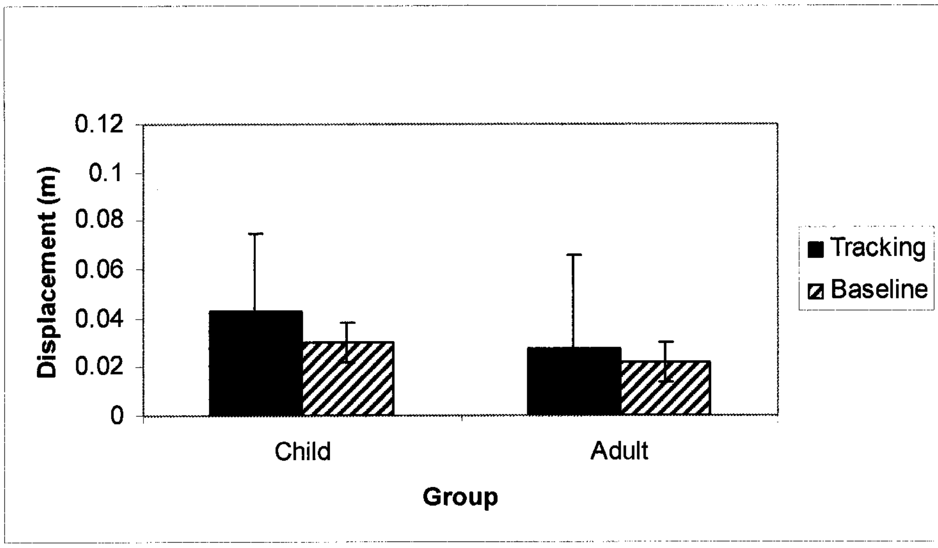


Figure 4.2-Mean Total Displacement (SD) Group main effect in the AP direction for both Baseline and Tracking Conditions.

There was also a main effect revealed for Focus [F= (1, 36) = 4.12, p≤0.05]. The participants in the External Focus group showed significantly greater displacement in the AP direction than the participants in the Internal Focus group as shown in Fig. 4.3.

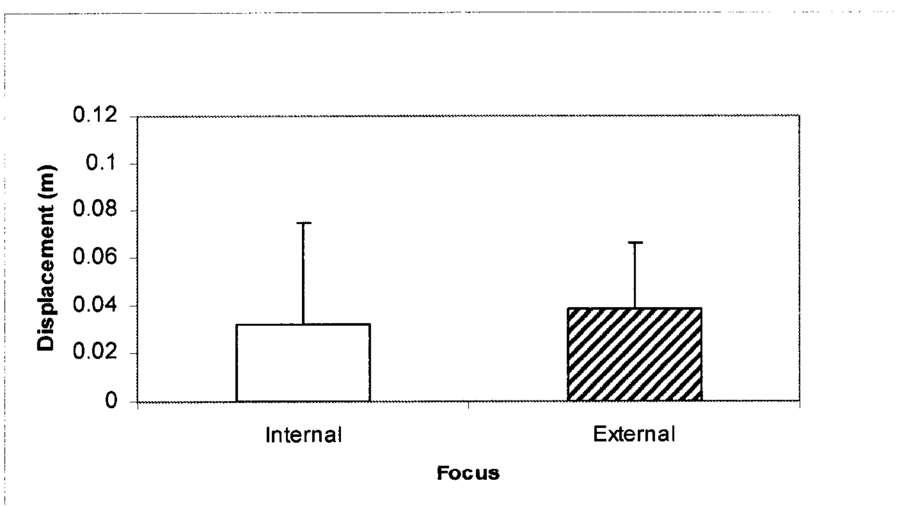


Figure 4.3 Focus main effect for total displacement in the AP direction.

There was one two-way interaction for Group and Trial in AP Total Displacement [F (2, 72) = 3.41, $p \leq 0.05$]. Post hoc analyses revealed that children had greater total sway than adults in all three trials, with Trial 2 showing the greatest difference (See Figure 4.4).

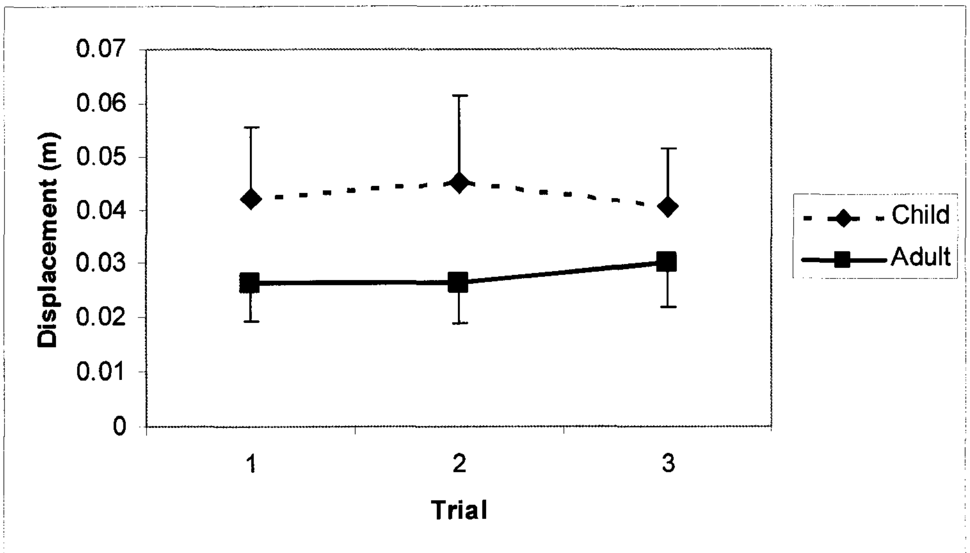


Figure 4.4- Group by Trial interaction for Total AP displacement.

The ML direction total displacement also revealed significant main effects for Group in both the Baseline [F (1, 38) = 12.26, $p \leq 0.05$] and Tracking [F (1, 36) = 12.45, $p \leq 0.05$] conditions. Again, in both conditions, child participants showed a greater total displacement than the adult participants (See Figure 4.5).

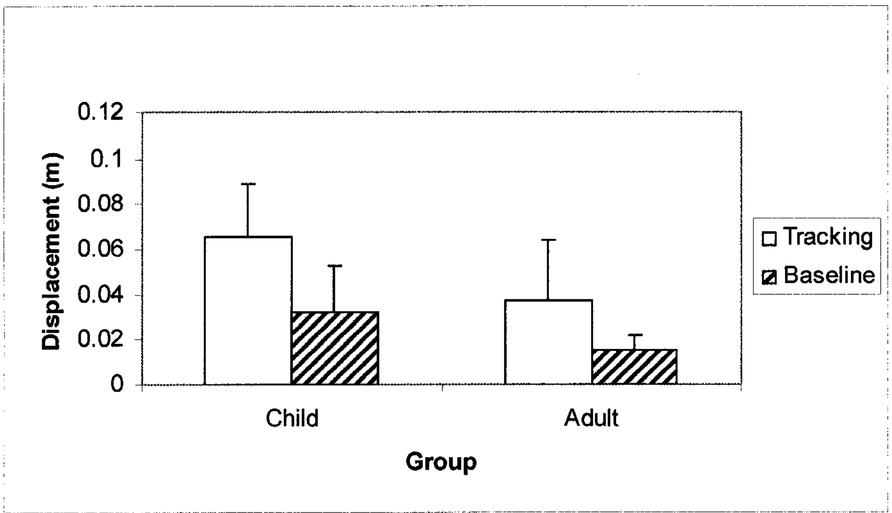


Figure 4.5- Group main effect for both Baseline and Tracking conditions for Total ML Displacement.

Comparing displacement values between AP and ML direction reveals greater displacement in the ML direction. This suggests that ML was the primary direction of sway for all participants.

4.2.2 Standard Deviation (Variability)

The ANOVA performed for AP variability revealed significant main effects for Group in both Baseline [$F(1, 38) = 12.74$, $p \leq 0.05$] and Tracking [$F(1, 36) = 17.60$, $p \leq 0.05$] conditions, with children exhibiting greater variability than adults (See Figure 4.6).

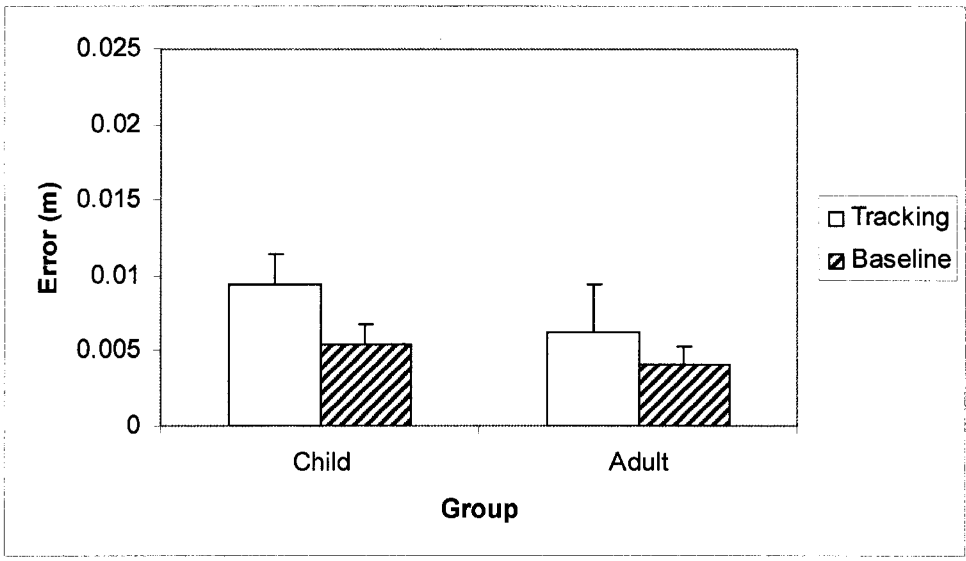


Figure 4.6-Group main effect for AP variability in both Baseline and Tracking conditions.

There was also a significant Focus main effect [F (1, 36) = 5.19, p≤0.05]. Participants in the External Focus group showed higher variability in the AP direction than participants in the Internal Focus group (See Figure 4.7).

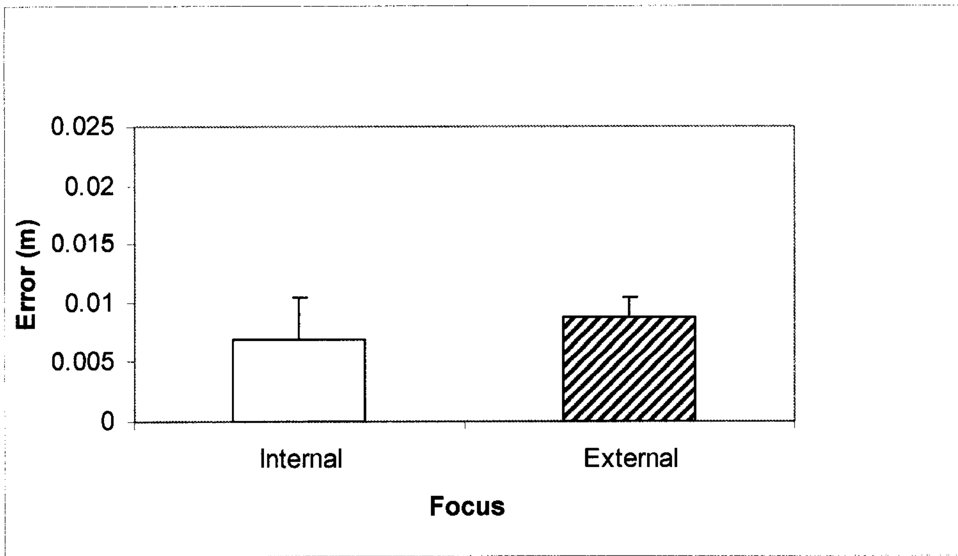


Figure 4.7- Focus main effect for AP variability (m).

A significant Group main effect was also found for ML variability for group in both Baseline [$F(1, 38) = 14.59$, $p \leq 0.05$] and Tracking [$F(1, 36) = 10.79$, $p \leq 0.05$] conditions. However, in contrast to the AP variability, adults showed a greater increase in variability than the children in the Tracking condition, but children still had a greater variability in the Baseline condition (See Figure 4.8).

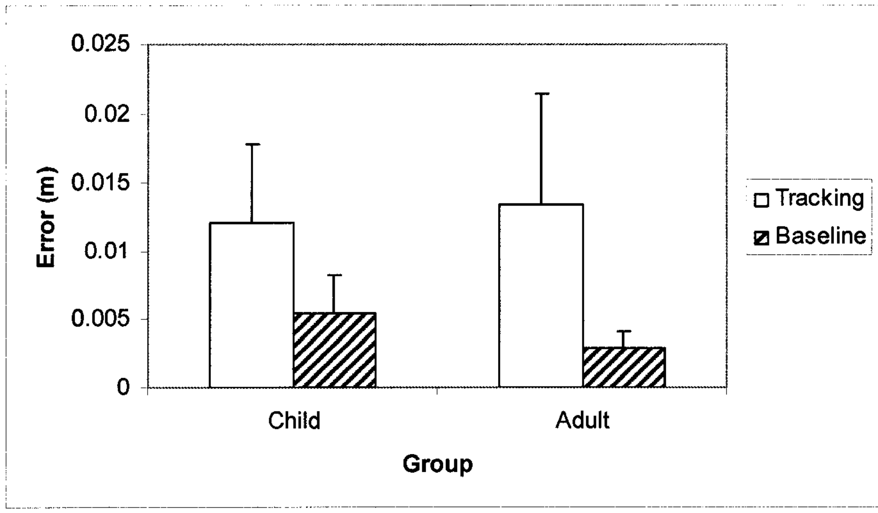


Figure 4.8-Group main effect for ML variability (m) in both Baseline and Tracking conditions.

4.2.3 Mean Power Frequency

The MnPf for each subject reflects the Tracking Frequency. The Tracking Frequency for the children ranged from .186Hz – 0.456Hz, and for the adults .199Hz – 0.529Hz. The analysis for the AP MnPf showed a two-way interaction between Group and Focus in the tracking conditions [F (1, 36) = 4.23, p≤0.05]. There were no group differences in the Internal Focus condition, however when using External Focus, adults exhibited a higher frequency than children (See Figure 4.9).

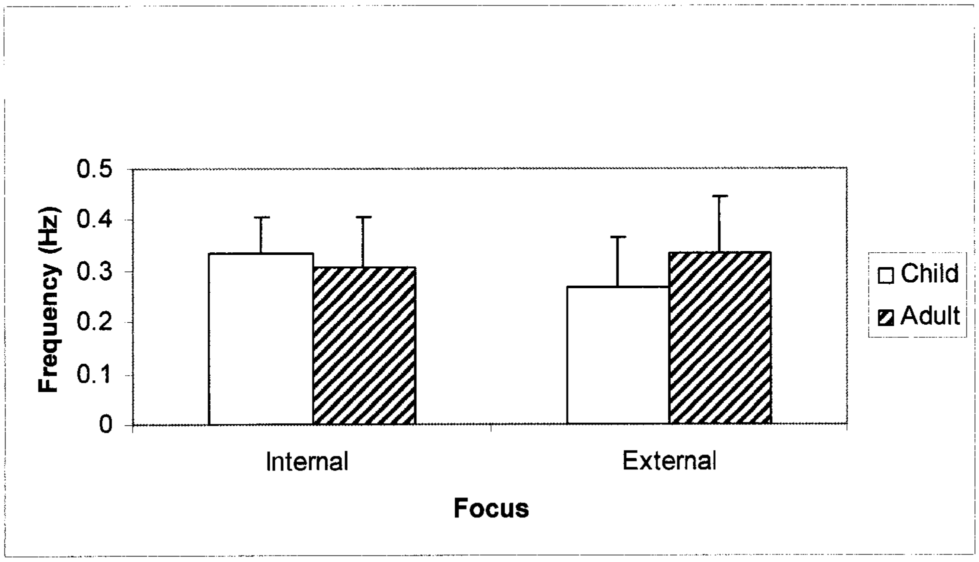


Figure 4.9- Group by Focus interaction for AP MnPf.

A two-way interaction was also found between Group and Trial [$F\ (2, 72) = 4.76$, $p \leq 0.05$]. Post hoc analysis revealed that there were no differences in AP MnPf during Trial 1 and Trial 2, but significant group differences for Trial 3. Children exhibit higher frequency than adults for Trial 3 (See Figure 4.10).

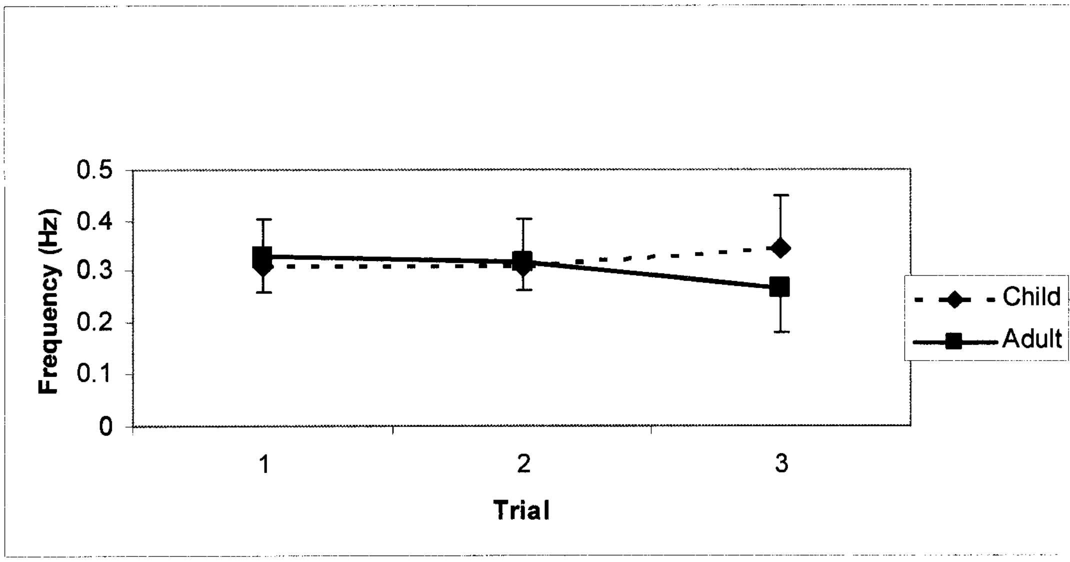


Figure 4.10- Group by Trial interaction for AP MnPf.

The analysis performed for ML MnPf revealed a significant main effect for Focus [F (1, 36) = 6.33, p≤0.05]. Participants in the External Focus group showed a higher ML MnPf, than participants in the Internal Focus group as shown in Figure 4.11.

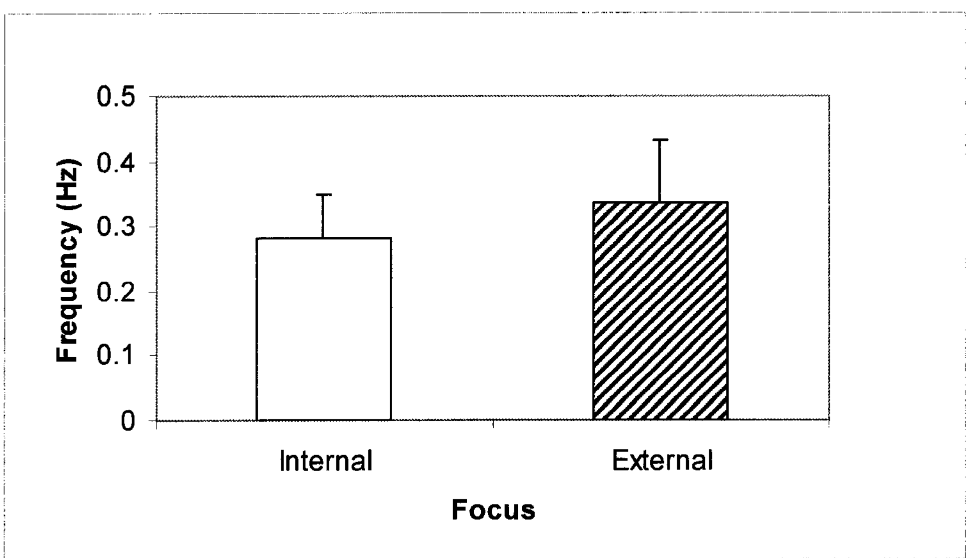


Figure 4.11- Focus main effect for ML MnPf.

4.2.4 Coupling

Given the fact that both children and adults performed the tracking task at a frequency that was 120% of their baseline MnPf, they may have been able to couple their MnPf to the Tracking Frequency. In fact a two-way interaction was found between Group and Trial for coupling in the AP direction [F (2, 72) = 4.69, p≤0.05]. Post hoc analysis indicated that there were differences between children and adults during Trial 3. With increased trials, the children became more coupled to the Tracking Frequency and the adults became less coupled to the Tracking frequency. This relates to the results which indicate that the children sway more in the AP direction than the adults (See Figure 4.12).

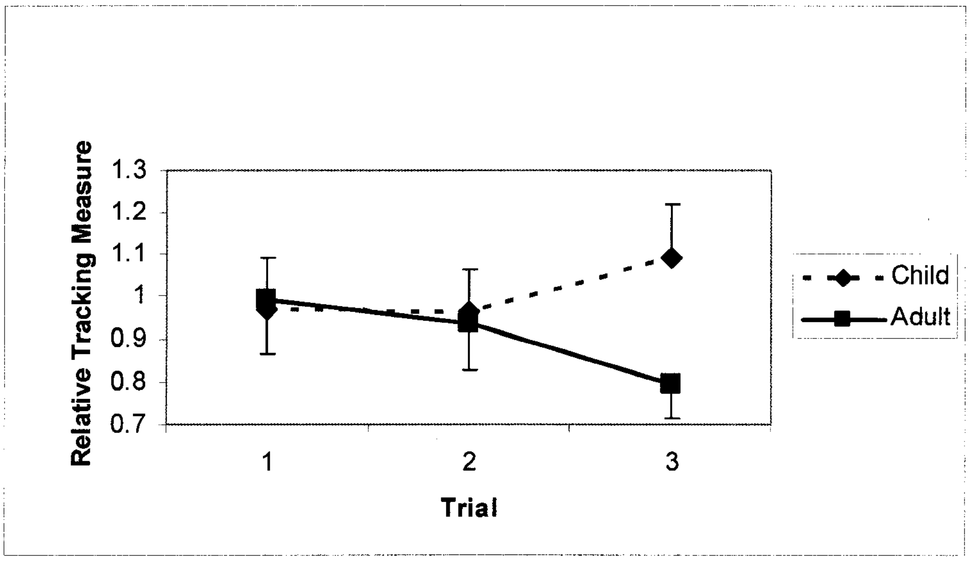


Figure 4.12- Group by Trial interaction for Coupling of MnPf (Relative Tracking Measure)

4.2.5 Velocity of Centre of Pressure

The ANOVA performed for the velocity of the centre of pressure (COP) indicated significant findings for group, in both the baseline [F (1, 38) = 23.88, p≤0.05] and the tracking [F (1, 36) = 9.08, p≤0.05] conditions. As shown in Fig. 4.13, the child participants had a larger average velocity, in both the baseline and tracking conditions, than their adult counterparts. Also, the child participants had a larger increase in velocity from the baseline to tracking measures than the adult participants.

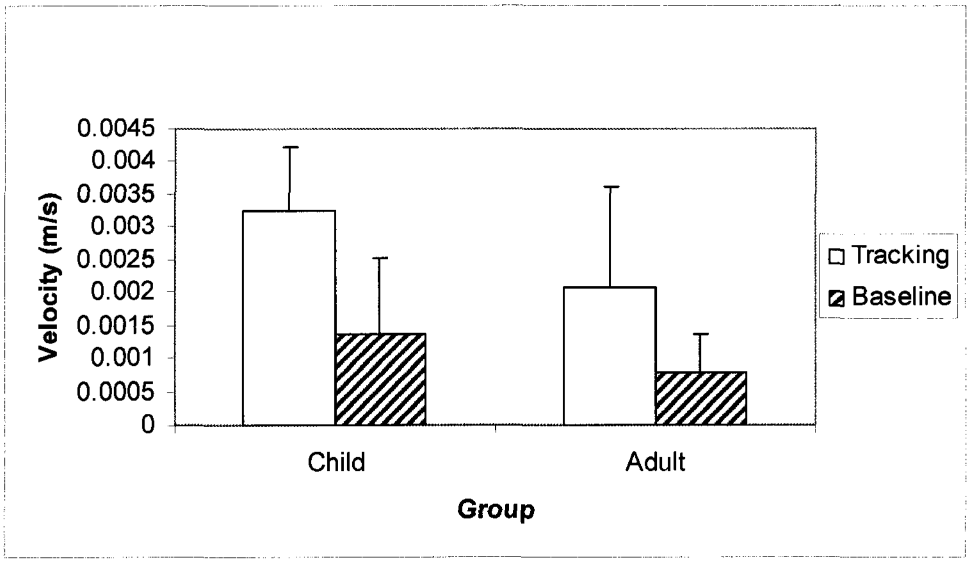


Figure 4.13- Group main effect for velocity of COP in both Baseline and Tracking conditions.

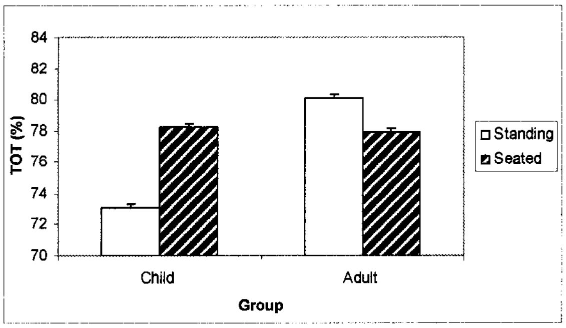
4.3 Performance Measure

4.3.1.Time on Target

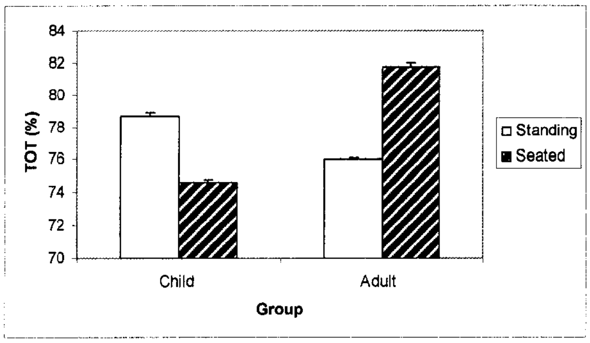
There was a significant three-way interaction revealed between group, trial and posture [F (2, 72) = 4.68, p≤0.05]. Post hoc analysis revealed that for Trial 1 in the standing condition, adults had better tracking performance than children (see Figure 4.14 a) There were no significant differences for standing on Trials 2 and 3.

In the Seated Posture condition, the adult participants and child participants start off with equal performance in the first trial, then the adults show improvement in TOT, whereas the children show a decrease in TOT. Post hoc analysis identified superior performance in Trials 2 and 3 for Adults (see Figure 4.14 b and c).

a)



b)



c)

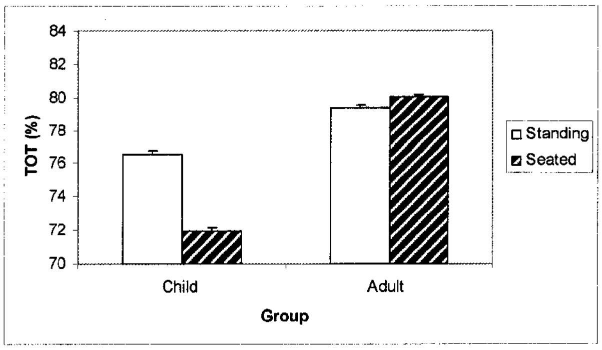


Figure 4.14- Trial by Group by Posture 3-way interaction for Time on Target during Trials 1(a), 2(b), and 3(c).

CHAPTER V

Conclusions and Recommendations

5.1 Postural Control

5.1.1 Attentional Focus

Previous research supports the "hypothesis of constrained action" by Wulf and colleagues (1998, 1998, 2001, 2001, 2002, 2003), which states that focusing internally causes constraints on systems of the body that would otherwise operate using automatic processing. A constrained system in terms of postural control would exhibit minimal displacement and variability. In contrast, focusing externally allows the automatic systems to release degrees of freedom and perhaps enhance performance by reducing the disruptions to the system. The data from the current study parallels the advantage of using external focus.

The participants in the External Focus group showed significantly greater displacement in the AP direction and greater variability than the participants in the Internal Focus group. Perhaps focusing attention outside of the body, allowed the automatic postural system to release degrees of freedom and operate with fewer constraints, thereby demonstrating more displacement and higher variability of COP movement.

The interactions between Group and Focus for AP MnPf, suggest that when adults used external focus, they had a higher sway frequency than children. This may reflect that adults have more rapid detection and correction mechanisms, which would suggest more automatic processing, as faster response time is a key characteristic (Schneider & Shiffrin, 1977). Schneider and Shiffrin (1977) also found that experience played a significant role in the development of automatic processing, which explains why adults would have been using a more automatic postural strategy than children. This experience may also have interacted with the external focus to aid in the release of these automatic postural strategies. In contrast, children had a higher sway frequency (AP Mnpf) when using internal attentional focus which supports the differences between adults and children with regards to experience and cognitive development (Schneider & Shiffrin, 1977; Bee, 2000). Recall that schema development is the action of categorizing or creating mental representations of actions, if children have difficulty doing this, they may be using more controlled processing, which would explain the inability to use external focus to release constraints on posture.

5.1.2 Age Groups

According to studies by Riach & Starkes (1994) and Kirshenbaum et al. (2001), children possess postural characteristics that differ from those of adults. Children have larger displacement, higher velocity as well as greater variability which results from overcompensating in response to movement of the COG.

Overall, children had greater COP displacement than adults in both AP and ML directions. This can be attributed to the fact that children had not yet developed the ability to minimize sway when necessary, thus resulting in overcompensating movements (See

Fig.5.1) During all 3 Trials, children exhibited greater AP displacement than adults, which indicates that even with practice the children were not able to minimize the unnecessary sway. Again, this may be related to the use of controlled processing, which is slower than automatic processing (Schneider & Shiffrin, 1977). Therefore the children had a slower response to COG movement resulting in higher displacement before error detection and correction mechanisms occurred. In contrast, the adults were able to moderate the amount of sway to perform the task, which resulted in lower displacement than the children (see Fig. 5.2).

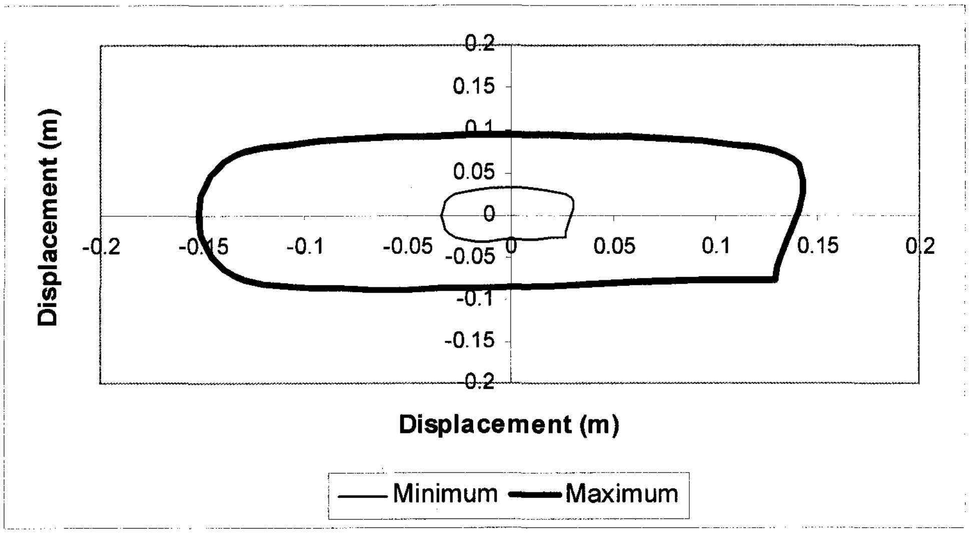


Figure 5.1- Minimum and Maximum COP Displacement plot for children during tracking.

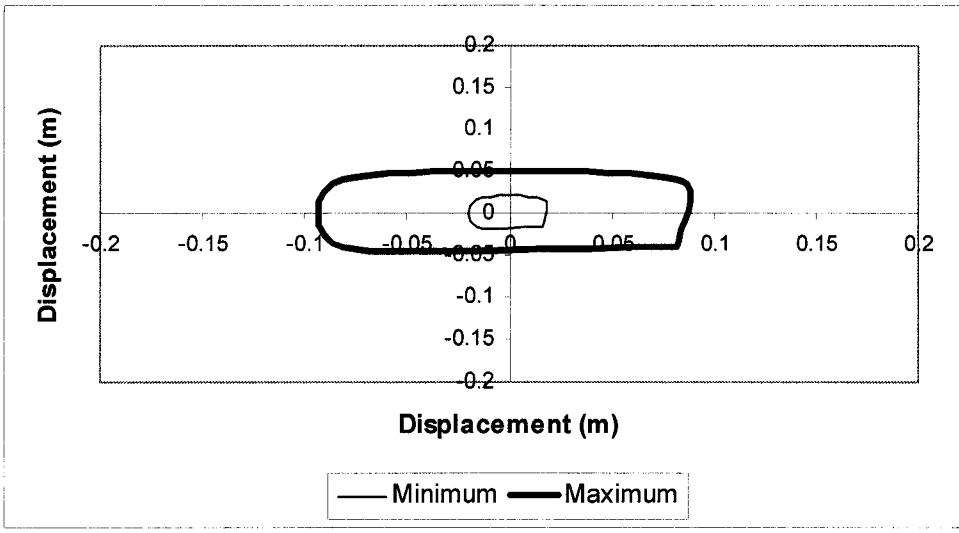


Figure 5.1- Minimum and Maximum COP Displacement plot for adults during tracking.

Previous research has shown that a typical postural characteristic of healthy adults is that they exhibit greater AP sway than ML sway during a two legged stance (Suomi & Koceja, 1994). The results of the current study contradict these findings, as both children and adults had higher ML displacement than AP displacement. This difference may be attributed to the suprapostural task demand of ML movement, and the constraints imposed on AP displacement, thereby increasing ML postural sway. This again highlights the coupling between the suprapostural task and the postural control system. Not only did the total displacement vary among participant groups, but the level of variability in postural sway. In the baseline condition, children exhibited greater variability in both AP and ML directions, indicating that even during quiet stance, there were differences in the maturity of the postural control systems. This variability may indicate the use of controlled processing in children, as one of the characteristics is flexibility; which allows variability in the system. The fact that children have less experience controlling their posture than adults, means that they may be more flexible to changing their postural behaviors. When children were tracking, they demonstrated higher variability than adults in the AP direction, however, in the ML direction children had lower variability than the adults. Recall that the demands of the tracking task promoted sway in the ML direction as the light rotated parallel to the frontal plane of the participant. Given the fact that the adults have more developed postural control, they were able to adopt this ML movement and variability to meet the task demands, whereas children, due to the difference in maturity of their postural system, were not able to adopt the characteristics of the tracking task thereby leading to less efficient postural mechanisms.

In addition to the variability, children also exhibited higher sway velocity in both AP and ML directions. This is consistent with findings from Riach & Startkes (1994) and Kirshenbaum et al. (2001), where children employed a primarily high velocity, ballistic strategy, making large and fast corrections of the centre of pressure to maintain the centre of pressure within the base of support. Kirshenbaum et al. (2001) indicated that there was a decrease in velocity after 7 years of age, however our results indicate that even from ages 9 to 11 years old, children still exhibit higher sway velocities than adult counterparts.

5.2 Tracking Performance

The performance data resulted in the most complex interaction among study variables. This interaction differentiated between standing and seated conditions and the role that initial exposure to the task played. Specifically, during Trial 1 of the Standing condition adults had better tracking performance than children. This may not be particularly surprising given that adults have more experience in controlling posture during a variety of suprapostural tasks. This may have allowed them to adapt immediately to the novel tracking task. Conversely, children may be employing semi-automatic processing to maintain posture, which is serial in nature, meaning that interference could occur with other controlled processing (Schneider & Shiffrin, 1977). This interference would occur as the task of postural control required more attention, resulting in a disruption in attending to the tracking task. The divided attention would cause a decrease in performance. If a true interference effect was present it was short lived, as on Trials 2 and 3 of the Standing condition there were no differences in tracking performance between children and adults. In fact, the tracking performance of the children improved slightly, while the performance of adults decreased slightly.

For the Seated condition, there were no differences on the first trial. In contrast, on both Trials 2 and 3, adults had better tracking performance than children. In fact, the children's performance decreased quite significantly, while that of adults improved considerably. This pattern is opposite to what occurred in the Standing condition. It could be that children were better at tracking in the more difficult Standing condition because the movement of their body was facilitating performance. This idea is supported by the relative coupling measure which showed that children were more coupled by Trial 3 than the adults for the Standing condition. The fact that children were able to couple their posture to the frequency of the tracking task indicates a relationship between controlled and automatic processing. The controlled processing of the tracking task was able to engage the semi-automatic processing of the postural system, because of the inherent flexibity available to controlled processing. Most importantly this indicates that children are able to use information in the environment to effectively influence postural behavior. While the results for the children are compelling, the adult findings do not support the previous work by Jeka et al. (1998) who showed that the adult participants exhibited strong coupling between body sway and rotating touch plate movement. , Jeka and colleagues suggested that this coupling occurred when the frequency of the touch plate was less than or equal to 0.4 Hz. While the tracking frequency for both children and adults in the current study fell within that range, adults did not exhibit the same strength of coupling. Extending Jeka's results, the children were able to couple the tracking and postural control systems. These differences might be explained by the more controlled nature of the children's information processing, or simply that the children were more dependant on the task to dictate their postural control.

In conclusion, this prelimary study uncovered many interesting developmental differences. Overall, the data were clear in supporting differences in information processing capabilities between children and adults, highlighting the potential benefits of the inherent flexibility available to the developing motor control system of children. While external focus did not enhance tracking performance it did have some effect on the characteristics of the emerging postural control. The lack of performance effect may have been due to the continuous nature of the tracking task. This task was very different than what has been used in previous studies. It could be that constantly updating the position of the limb during the tracking task diminished the potential benefits of focusing outside the body. The previous studies had as their goal the minimization of excessive sway, and did not require the tracking of an additional stimulus. Sway was an inherent component of the current task as a result of tracking the lighted stimulus. These task differences, coupled with the developmental differences require further consideration in future research.

5.4 Limitations

Unfortunately, one of the limitations that plague studies involving the manipulation of cognitive strategies, such as attentional focus, is that the experimenter can never be sure that the participant is using the correct strategy. To ensure the participants followed attentional focus instructions, a brief questionnaire could have been administered following the testing session. Second, while a standardized instruction protocol was read to each participant, some participants asked for further clarification. Thus, some participants may have received less instruction on attentional focus, possibly leading to reduced focus effects.

The recruitment of only right-handed female participants caused a limitation in the ability to generalize the findings to other populations. Although this decision was made to reduce hemispheric and gender differences, the results reflected a restricted population.

A fourth limitation of the current study arose from the fact that only COP was measured; thus, the results cannot be generalized for all postural components. The use of electromyography and a biomechanical measurement would provide more complete and thorough postural data, such as the activation and deactivation of the muscles controlling posture, and ankle joint angles.

A possible equipment limitation may have resulted from the fact that the same seat was used for all participants. Although the participants' feet were resting comfortably on the floor, providing an individualized seat height for each subject may have had an influence on seated postural control and tracking performance.

A final limitation in the current study may have arisen from the tracking task itself. Given the dynamic nature of he PR tracking task, it may have been too challenging for the participants to gain the full benefits of external attentional focus.

5.5 Future Directions

Given the lack of attentional focus effects on performance, it would be necessary to replicate these findings using a less dynamic task. Perhaps replicating one of the earlier tasks used by Wulf and colleagues would reveal "more traditional" attentional focus findings. If in using a more static task resulted in performance interactions between age groups and focus conditions, the present findings would speak to the potential limitations of the attentional focus paradigm.

Secondly, the findings of the current study pertain exclusively to females, but should be considered in the examination of gender differences in suprapostural tracking performance and postural control. This would allow findings to be generalized on a larger scale.

Lastly, given the different attentional capacities of adults and children with cognitive disorders, a follow up study could be designed to examine the effects of attentional focus on posture and task performance in atypically developed adults and children. These results could then be compared with individuals who are typically developed, in the hopes of gaining insight on pathological differences. The resultant findings could then be used to develop attentional focus strategies that could be pragmatically implemented into rehabilitation programs that assist adults and children in the achievement of their physical goals.

APPENDIX A

UNIVERSITY OF
WINDSOR

CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: The effects of attentional focus and posture on suprapostural task tracking performance: a developmental perspective.

You are asked to participate in a research study conducted by Ms. Tiffany Quinn and Dr. Patricia Weir from the Department of Kinesiology at the University of Windsor.

If you have questions or concerns about the research, please contact Ms. Tiffany Quinn at 253-3000 ext. 2457 or Dr. Patricia Weir at 253-3000 ext. 2443.

PURPOSE OF THE STUDY

The purpose of this study is to examine balance under conditions of either internal or external attentional focus during a tracking task. Attentional focus can be defined as which components the child focuses on during a task (internal- finger, external- a light).

PROCEDURES

If you consent for your child to volunteer to participate in this study you will be asked to: 1) fill out a short health survey questionnaire regarding the general health of your child, and 2) consent for your child to participate in a session that will measure your child's balance. To measure balance your child will be asked to stand comfortably on a force plate, which looks similar to a scale. The plate measures the forces applied in both the forward/backward and left/right directions by your child as he/she stands on the plate. At the same time your child will be asked to do a Pursuit Rotor task. This involves holding on to a hand-held stylus and following a light on a screen with the stylus as it moves in a circle. Your child will also be asked to perform the tracking task in a seated position. The anticipated duration of testing is 15 minutes.

POTENTIAL RISKS AND DISCOMFORTS

There are no anticipated risks in this study. A research assistant will stand by your child's side throughout testing to ensure that your child does not fall should he/she become unbalanced.

POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The anticipated benefits of your child's participation are an increased understanding of the scientific process and an understanding of balance under different conditions. The academic benefits of this study are an increased understanding of attentional focus and its effects on motor behaviour such as tracking abilities and balance.

PAYMENT FOR PARTICIPATION

Not applicable.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. During each study, each participant will be assigned a number which will be associated with their data throughout the collection and analysis. At the time of publication and/or presentation, no reference will be made to any individual participant number.

PARTICIPATION AND WITHDRAWAL

You can choose whether to allow your child to be in this study or not. If you consent for your child to volunteer to be in this study, you may withdraw your child at any time without consequences of any kind. You may also refuse to answer any questions you don=t want to answer and still remain in the study. The investigator may withdraw your child from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

If you would like a copy of the results of this study we will arrange to mail a copy to you at your home address.

SUBSEQUENT USE OF DATA

I agree that this data can be used in subsequent studies.

RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. This study has been reviewed and received ethics clearance through the University of Windsor Research Ethics Board. If you have questions regarding your rights as a parent/guardian of a research participant, contact:

Research Ethics Coordinator
University of Windsor
Windsor, Ontario
N9B 3P4

Telephone: 519-253-300ext. 3916
E-mail: lbunn@uwindsor.ca

SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study. "The effects of attentional focus and posture on suprapostural task tracking performance: a developmental perspective." as described herein. My questions have been answered to my satisfaction, and I agree to consent for my child to participate in this study. I have been given a copy of this form.

____
Name of Subject Parent/Guardian

____
Signature of Subject Parent/Guardian Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

____
Signature of Investigator Date

APPENDIX B

General Health Questionnaire

Subject #-------

DOB(m/d/y):

1) How would you rate your overall health?

Poor Fair Good Very Good Excellent

2) Have you ever experienced balance problems Y N

If yes, under what circumstances?

3) Do you have normal vision? Y N

If no, please answer part b)

b) Do you wear corrective lenses for correction of the following?

near-sightedness far-sightedness astigmatism

4) Do you experience muscle weakness? Y N

If yes, under what circumstances?

5) Do you experience any shoulder joint pain or limited range of motion in the shoulder joint?

If yes, under what circumstances? Y N

6) Do you take any regular prescription medication? Y N

If yes, what medication and for what condition?

7) How many hours per week are you physically active? ---------hrs

What activities do you participate in?

Thank You for your participation.

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